On Establishing Common Requirements for Water Mist Systems in Protecting Ordinary Combustible Fires

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Outline

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Background

Recent questions about Class A fire protection in the water mist fire protection community:

- ***What is the required operational area for water mist systems?***
- ***Can the requirements for fire sprinklers be applied to water mist systems?***
- ***Can the same operational area requirements be applied to different water mist systems?***

Class A Fire Suppression by Water - 1

Requirements:

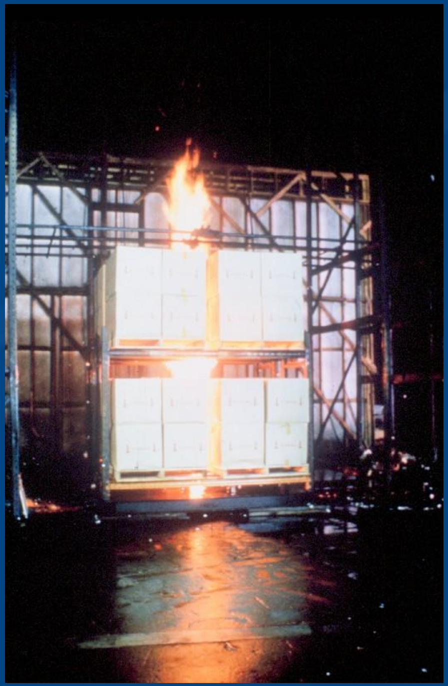
- Flame extinction in the gas phase
- Reducing fuel pyrolysis sufficiently

Controlling factors for fire suppression:

1) Spray characteristics – impact on cooling, inerting fire environment, radiation attenuation, fire plume penetration capability
2) Fire Hazard
   - Building height and storage height
   - Ventilation condition
   - Fuel properties – flammability and water absorption propensity
   - Storage arrangement
   - Surface or deep-seated fire
   - Degree of obstruction between fire and spraying nozzles

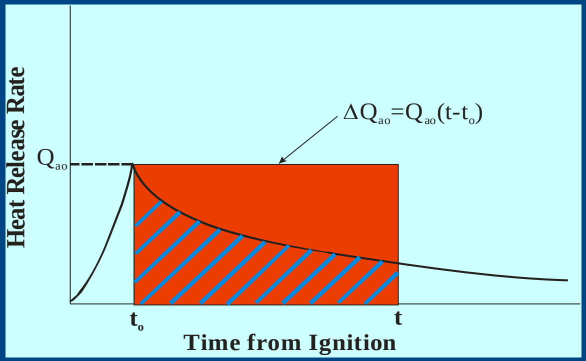
Class A Fire Suppression by Water - 2

Two-tier Fire Suppression Test



Class 2 Commodity	Plastic Commodity
	

Number of Tiers	Fire Suppression Water Flux for $\Delta Q_a / \Delta Q_{ao}$=0.67 in 240-s Water Application (mm/min)	
	Class 2 Commodity	Plastic Commodity
2	6.9	11.4
3	10.5	16.3
4	13.4	21.2



Droplet size impact -1

For the same amount of water in the space,

$N \sim 1/d^3$, N= droplet number density

$A_w \sim 1/d$, A_w= total droplet surface area

The vaporization rate per droplet:

$$\dot{m}_d = 2\pi d \left(\frac{k}{C_p}\right)_g \ln\left(1 + \frac{Y_{d,surface} - Y_\infty}{1 - Y_{d,surface}}\right)$$

The total vaporization rate $= N\dot{m}_d \sim 1/d^2 \Rightarrow$

The smaller the droplet, the greater cooling and inerting

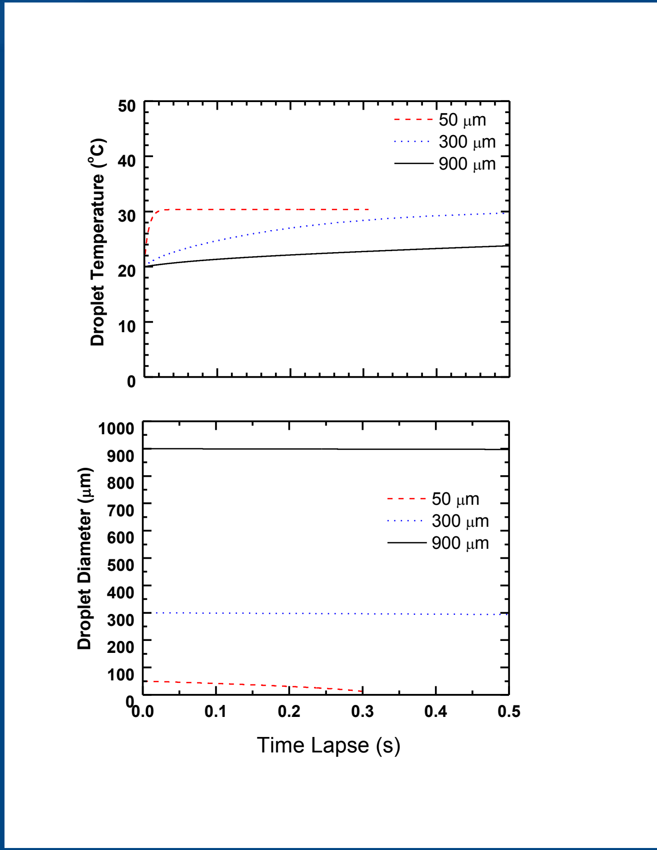
Thermal radiation transmission ~ $e^{-kf_v/d}$, f_v= *water volume fraction*

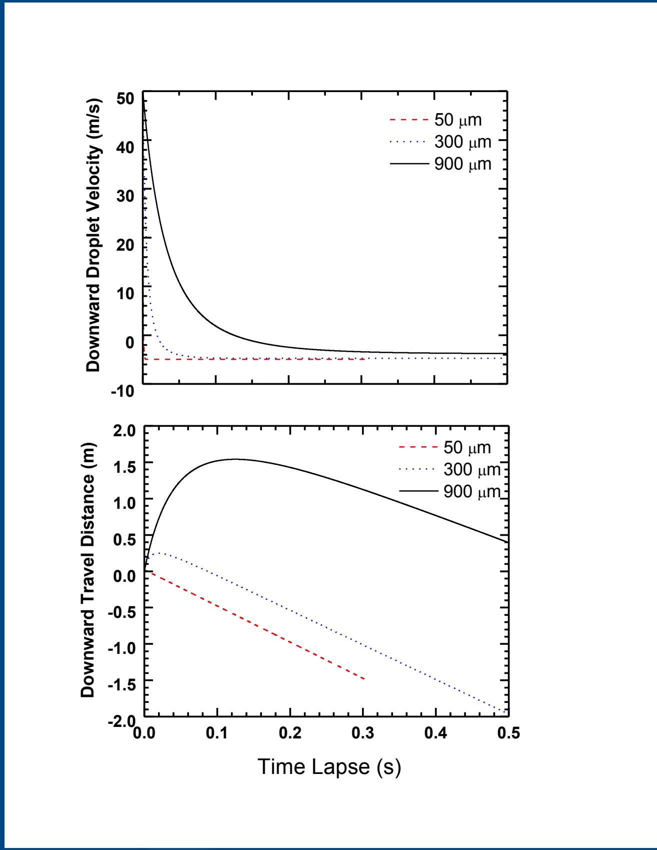
$\Rightarrow$ the smaller the droplet, the greater the attenuation.

Droplet size impact – 2

An example of the evolution of a single droplet injected into opposing air stream :

- A droplet at a starting temperature of 20 °C is discharged downward into a 100 °C dry air stream
- Air velocity: 5 m/s upward
- Starting droplet velocity: 50 m/s downward





Droplet size impact – 3

An Example of Water Spray Penetration Propensity:

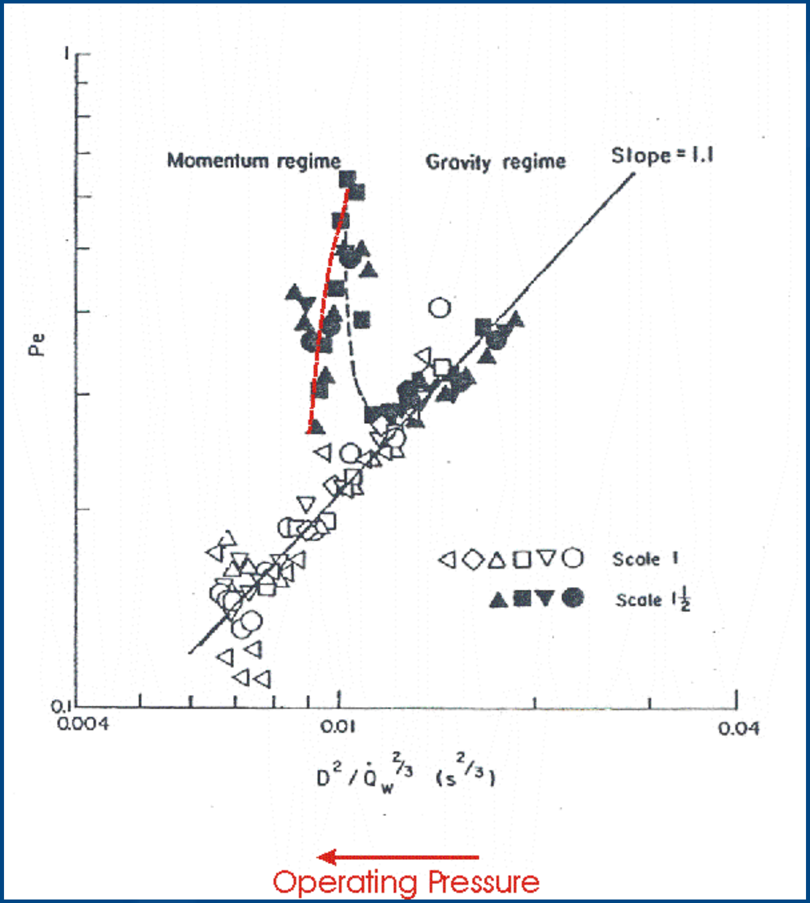
Droplet diameter $\propto D^{2/3}P^{-1/3} \propto (D^2 / \dot{Q}_w^{2/3})$

D = Nozzle orifice diameter

P = Nozzle operating pressure

$\dot{Q}_w$ = Water discharge rate

Pe = Fraction of water flux reaching the fire plume base



The Case of Fire Sprinklers -1

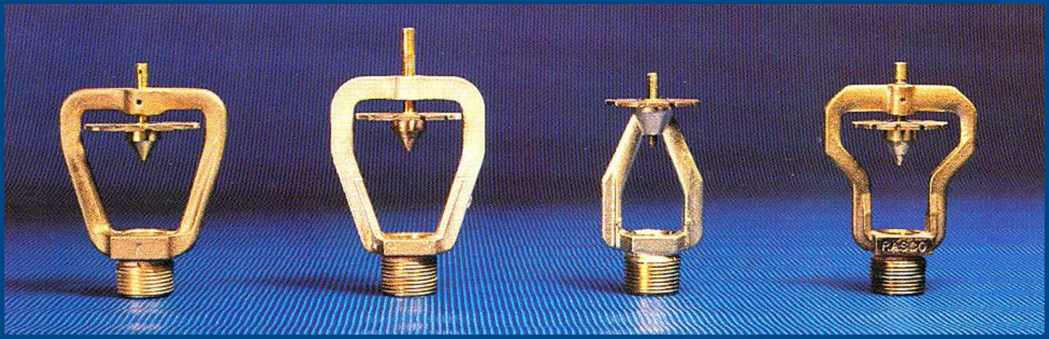
- For the protection of a fire hazard, approval standards, such as FM Approvals Class 2000 and Class 2008, require that sprinklers have to meet certain water spray distribution and penetration requirements. As a result, different sprinkler models in a system category tend to:
  1) have the same or similar orifice diameters
  2) operate at the same or comparable pressures
     $\Rightarrow$ comparable discharge rates and droplet sizes
  3) have the same or similar spray angles and nozzle spacings
     $\Rightarrow$ comparable penetration capabilities
- Installation standards, such FM Global OS 8-9 and NFPA 13, can therefore impose the same water supply requirement and operational area for different sprinkler models in a system category.

The Case of Fire Sprinklers – 2

An example:

- The ESFR sprinklers have to meet certain spray penetration requirements in ADD (Actual Delivered Density) measurements.

- Comparable spray patterns, droplet sizes and discharge rates at the same operating pressures among different ESFR sprinklers



The Case of Water Mist Systems – 1

- Current standards, such as FM Approvals Class 5560 and CEN TS 14972, do not impose water mist spray requirements for certification of protecting a fire hazard. The systems are certified as is by fire testing.
- For the same protection, the systems could be very different:
  - ✓ single-fluid or twin-fluid
  - ✓ Different gases used in twin-fluid systems, such as air, N_2, CO_2
  - ✓ single-orifice or multiple-orifice
  - ✓ wide range of operating pressures (up to 140 bar or higher)
  - ✓ wide range of spray angles
  - ✓ Wide range of droplet sizes (as long as smaller than 1000 µm for 99% of discharged rate per NFPA 750)

The Case of Water Mist Systems – 2

- For different systems, the different fire suppression mechanisms, such as gas-phase cooling, fuel cooling, oxygen displacement, fuel vapor dilution, radiation attenuation and others, may play at different levels of significance in the fire suppression process.

  $\Rightarrow$ Affect the protection result

- For instance, a system conducive to droplet evaporation, which is expected to be better at gas-phase cooling, oxygen displacement, fuel vapor dilution and radiation attenuation, may need a larger operational area in an open environment, as compared to a system having a better capability in delivering water to the fire source to directly cool the burning combustibles.

Recommendations

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To be able to impose the same operational area requirement for different water mist systems, and to achieve comparable fire protection result for a fire hazard in an open environment:

- Group water mist systems in a way similar to that for fire sprinkler systems.

- Include spray characteristics in the grouping process, i.e. droplet size, water flux, thrust force and their distributions.

Questions?